

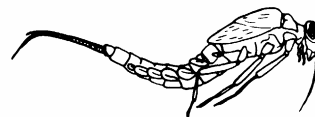
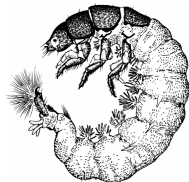
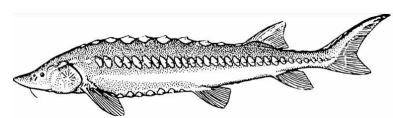
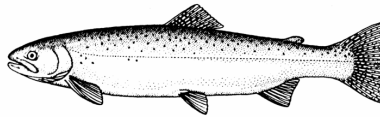
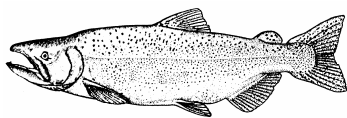
**IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS
FOR ANADROMOUS FISH IN THE STREAMS WITHIN
THE CENTRAL VALLEY OF CALIFORNIA**

**Annual Progress Report
Fiscal Year 2007**

U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825



Prepared by staff of
The Energy Planning and Instream Flow Branch



PREFACE

The following is the sixth annual progress report prepared as part of the Central Valley Project Improvement Act Instream Flow Investigations, an effort which began in October, 2001.¹ Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Department of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide scientific information to the Service's Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley streams and rivers.

The field work described herein was conducted by Ed Ballard, Mark Gard, Rick Williams, Bill Pelle, Nick Hindman, Timothy Blubaugh, Hayley Potter and Jacob Cunha.

Written comments or questions can be submitted to:

Mark Gard, Senior Biologist
Energy Planning and Instream Flow Branch
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825

Mark_Gard@fws.gov

¹ This program is a continuation of a 7-year effort, also titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. The proposal included completing instream flow studies on the Sacramento and Lower American Rivers and Butte Creek which had begun under the previous 7-year effort, and conducting instream flow studies on other rivers, with the Yuba River selected as the next river for studies. The last report for the Lower American River study was completed in February 2003 and the final report for the Butte Creek study was completed in September 2003. In 2004, Clear Creek was selected as an additional river for studies. In 2007, the Tuolumne River was selected for a minor project to quantify floodplain inundation area as a function of flow.

The Sacramento River study was planned to be a 7-year effort originally scheduled to be concluded in September 2001. Specific goals of the study were to determine the relationship between streamflow and physical habitat availability for all life stages of Chinook salmon (fall, late-fall, winter-runs) and to determine the relationship between streamflow and redd dewatering and juvenile stranding. The study components included: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The first eight study components were completed by Fiscal Year (FY) 2005. The FY 2007 Scope of Work identified study tasks to be undertaken. These included: complete final reports on macroinvertebrate flow-habitat relationships and on redd dewatering and juvenile Chinook salmon and steelhead stranding. These final reports were both completed in December 2006.

The Yuba River study was planned to be a 4-year effort, beginning in September 2001. The goals of the study are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-runs) and steelhead/rainbow trout and to determine the relationship between streamflow and redd dewatering and juvenile stranding. Collection of spawning and juvenile rearing criteria data for fall- and spring-run Chinook salmon and steelhead/rainbow trout was completed by, respectively, April 2004 and September 2005. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run and fall-run Chinook salmon and steelhead/rainbow trout was completed in FY 2005. Field work began in FY 2004 to determine the relationship between habitat availability (juvenile rearing) and streamflow for spring-run and fall-run Chinook salmon and steelhead/rainbow trout, and was completed by FY 2005 for all but two sites. Data collection on these two remaining juvenile rearing sites was completed in FY 2007.

In FY 2007, we generated flow-habitat relationships for spring/fall-run Chinook salmon and steelhead/rainbow trout rearing for the segment downstream of Daguerre Point Dam and completed hydraulic modeling of the rearing sites upstream of Daguerre Point Dam. In addition, we completed the response-to-comments document for the peer review of the spawning study report and revisions to the draft spawning study report stemming from the peer review, and sent the draft report and response-to-comments document out for stakeholder review². The remaining work on the Yuba reports is ongoing, including responses to stakeholder comments for the spawning report. With regards to the rearing report, remaining analyses include generating flow-habitat relationships for spring/fall-run Chinook salmon and steelhead/rainbow trout rearing for the segment upstream of Daguerre Point Dam.

The Clear Creek study is a 5-year effort, the goals of which are to determine the relationship between stream flow and physical habitat availability for all life stages of Chinook salmon (fall- and spring-run) and steelhead/rainbow trout. There will eventually be four phases to this study based on the life stages to be studied and the number of segments delineated for Clear Creek from downstream of Whiskeytown Reservoir to the confluence with the Sacramento River³. The four phases are: 1) spawning in the upper two segments; 2) fry and juvenile rearing in the upper two segments; 3) spawning in the lower segment; and 4) fry and juvenile rearing in the lower segment. In FY 2004 staff of the Service's Red Bluff Fish and Wildlife Office began collecting HSC data for spring-run Chinook salmon and steelhead/rainbow trout spawning and fry and juvenile rearing. Field work to determine the relationship between habitat availability (spawning) and streamflow for spring-run Chinook salmon and steelhead/rainbow trout in the upper two segments was completed in FY 2005. In FY 2007 the final report and the peer review response-to-comments document for spawning in the upper two segments was completed, as was data collection on two of the upper segment rearing sites and three of the lower segment spawning sites. Data collection for the remaining two lower segment spawning sites is ongoing, as is hydraulic modeling of the final two upper segment rearing sites and collection of HSC data for spring and fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing. We anticipate proceeding with the selection of rearing study sites in the Lower Alluvial Segment after habitat mapping is completed in early FY 2008.

The following sections summarize project activities between October 2006 and September 2007.

² Stakeholder review for the Yuba reports was agreed upon during scoping meetings prior to commencement of the studies.

³ There are three segments: the upper alluvial segment, the canyon segment, and the lower alluvial segment. Spring-run Chinook salmon spawn in the upper two segments, while fall-run Chinook salmon spawn in the lower segment and steelhead/rainbow trout spawn in all three segments.

SACRAMENTO RIVER

Habitat Suitability Criteria Development

Macroinvertebrate criteria

We have developed a second set of juvenile Chinook salmon HSC - one based on food supply rather than physical habitat. Specifically, we developed HSC in FY 2005 for macroinvertebrate biomass and diversity. The criteria we developed were run on the juvenile rearing site habitat models to predict the relationship between flow and habitat area for macroinvertebrate biomass and diversity. We completed our sampling for macroinvertebrate criteria in FY 2001, with a total of 75 macroinvertebrate samples (22 in riffles, 20 in runs, 13 in pools and 20 in glides). Processing of samples, and computation of biomass and diversity represented by each sample, was completed under contract in July of 2004. HSC were developed in FY 2005 for macroinvertebrate production and diversity as determined by depth, velocity, and substrate size based on the biomass and diversity determined for the samples. Statistical analysis found that the 75 samples collected were sufficient to generate HSC. These criteria were applied to the 2-D modeling results of the rearing sites between Keswick Dam and Battle Creek to generate flow-habitat relationships. The final report and peer review response-to-comments document was completed and issued in December 2006.

Habitat Simulation

Chinook salmon and steelhead juvenile stranding and redd dewatering

Stranding flows and stranding areas have been determined for all of the 108 juvenile Chinook salmon stranding sites. Using the HSC previously developed by the Service on the Sacramento River for fall, late-fall, and winter-run Chinook salmon spawning (U.S. Fish and Wildlife Service 2003) and on the lower American River for steelhead (U.S. Fish and Wildlife Service 2000), the percent loss of spawning habitat area versus flow was computed for Chinook salmon (fall, late-fall, spring-run) and steelhead over a range of discharges. The redd dewatering analysis was conducted using data from the 2-D models for our eight spawning sites from Keswick Dam to Battle Creek (Lower Lake Redding, Upper Lake Redding, Salt Creek, Bridge Riffle, Posse Grounds, Above Hawes Hole, Powerline Riffle and Price Riffle). Information on these sites is given in U.S. Fish and Wildlife Service 1999. The final report and peer review response-to-comments document on the juvenile Chinook salmon and steelhead stranding sites and redd dewatering analysis was completed and issued in December 2006.

YUBA RIVER

Hydraulic and Structural Data Collection

Juvenile Chinook salmon and steelhead/rainbow trout rearing

Hydraulic and structural data collection for six of the eight juvenile rearing study sites was completed in FY 2005. Hydraulic and structural data collection was completed in FY 2007 on the two study sites (Rosebar and Narrows) for which data collection was incomplete. Substrate and cover data (Tables 1 and 2) was collected at the outflow transect of the Rosebar study site and the inflow and outflow transects of the Narrows site. We also completed the collection of deep data between the Narrows transects which included: 1) bed elevation; 2) northing and easting (horizontal location); 3) substrate; and 4) cover. These parameters were collected at enough points to characterize the bed topography, substrate and cover of the site. To collect the remaining deep data between the Narrows inflow and outflow transects, a Broad-Band Acoustic Doppler Current Profiler (ADCP) was used in concert with a total station to obtain bed elevation and horizontal location. Specifically, the ADCP was run across the channel at 25 to 50-foot intervals, with the initial and final horizontal location of each run measured by the total station. The Water Surface Elevation (WSEL) of each ADCP run was measured with a level before starting the traverse. The WSEL of each traverse was then used together with the depths from the ADCP to determine the bed elevation of each point along the traverse. For the collection of the substrate and cover data on the ADCP traverses for this site, the initial and final locations of each deep bed elevation traverse were marked with buoys prior to the ADCP traverses. The substrate and cover were visually assessed using an underwater video camera system and a laser range finder was used to measure the stations along the ADCP traverses where the transitions in substrate and cover occurred so that substrate and cover values could be assigned to each point of the traverse.

Juvenile Chinook salmon and steelhead/rainbow trout stranding sites

In FY 2005, 75 sites were located between the Narrows and the confluence with the Feather River where stranding flows for juvenile Chinook salmon and steelhead/rainbow trout will be identified (Appendix A). Three main approaches were used to determine the stranding flows⁴ for the 75 stranding sites: 1) for those stranding sites located in one of our spawning or juvenile habitat modeling sites, the 2-dimensional hydraulic model of the spawning or juvenile habitat site will be used to determine the stranding flow for the stranding site; 2) for those stranding sites where the flow during our identification of the stranding site was at or slightly above or below

⁴ We have defined the stranding flow as the flow where the connection between the stranding area and main river channel has a maximum depth of 0.1 feet. We selected 0.1 feet because the minimum depth at which we have found juvenile salmon and steelhead/rainbow trout during our HSI data collection has been 0.2 feet. When flows drop to or below the stranding flow, juvenile salmon and steelhead/rainbow trout will be isolated from the main river channel.

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 – 1
1.2	Medium Gravel	1 – 2
1.3	Medium/Large Gravel	1 – 3
2.3	Large Gravel	2 – 3
2.4	Gravel/Cobble	2 – 4
3.4	Small Cobble	3 – 4
3.5	Small Cobble	3 – 5
4.6	Medium Cobble	4 – 6
6.8	Large Cobble	6 – 8
8	Large Cobble	8 – 10
9	Boulder/Bedrock	> 12
10	Large Cobble	10 – 12

the stranding flow for that site, we determined the stranding flow based on the flow on that date; and 3) for the remaining 49 sites, we developed a stage-discharge relationship for the main river channel at the stranding site to determine the stranding flow. In FY 2007 stage-discharge relationships were developed for all of the 49 stage-discharge stranding sites. Data required for developing a stage discharge relationship are: 1) water surface elevations (WSELs, stages) collected at three flows; and 2) the stage of zero flow. We also measured the bed elevation of the stranding point (the lowest point at the connection between the stranding area and the main river channel); the stage at the stranding flow was calculated by adding 0.1 feet to the bed elevation of the stranding point. After the stage discharge relationship is developed, it is used to determine what the flow is at the stranding flow stage. The stage of zero flow was determined by making an ADCP run across the main channel at the stranding point. The stage of zero flow was calculated as the difference between the WSEL on that date and the largest depth. We have measured WSELs at three flows and stranding bed elevations and determined the stage of zero flow for all 49 stage-discharge stranding sites.

Table 2
Cover Coding System

Cover Category	Cover Code
No cover	0
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

We completed stranding area data collection for all of the stranding sites in FY 2006. For smaller sites, we determined the area by measuring the length and two to six widths of the stranding site, using a tape or electronic distance meter; the area is calculated by multiplying the length times the average width. The areas of larger sites have been measured in GIS. The stranding sites data collection was completed in early January 2007 and a final report should be completed by September 2008.

Hydraulic Model Construction and Calibration

Juvenile Chinook salmon and steelhead/rainbow trout rearing

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-

generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The Physical Habitat System (PHABSIM) transect at the outflow end of each site is calibrated to provide the Water Surface Elevation's (WSEL) at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by the PHABSIM transect at the inflow end of the site⁵. The River2D model is run at the flows at which the validation data set was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

Compilation and QA/QC of the data for the eight rearing sites was completed in FY 2007. PHABSIM data decks have been created and hydraulic calibration has been completed for the inflow and outflow transects for all of the rearing sites. Construction and calibration of the 2-D models and production runs for five of the eight rearing sites was completed in FY 2006. In FY 2007, we completed the hydraulic calibration, bed files, computational meshes for the 2-D modeling program, calibration of the two-dimensional hydraulic models, and production runs for all of the simulation flows for the remaining three rearing sites.

Habitat Simulation

Chinook salmon and steelhead/rainbow trout spawning

A draft report and response-to-comments document was completed in FY 2007. In FY 2007, we sent out the draft report to interested parties for review and comment after the in-office review prior to finalizing the report. This review by interested parties is in response to commitments made by the Service during the initial planning meetings with those interested parties. This is the first of the CVPIA instream flow reports to be reviewed in this manner. With response to interested party comments ongoing, a final report on flow-habitat relationships for spawning and the response-to-comments document should be completed by early 2008.

⁵ This is the primary technique used to calibrate the River2D model.

Juvenile Chinook salmon and steelhead/rainbow trout rearing

Spring/fall-run Chinook salmon and steelhead/rainbow trout fry and juvenile rearing habitat was computed over a range of discharges in FY 2007 for six of the eight rearing study sites. Significant portions of the draft report were completed in FY 2007. The draft report, peer review, response-to-comments document and final report on flow-habitat relationships for rearing should be completed by September 2008.

CLEAR CREEK

Hydraulic and Structural Data Collection

Juvenile spring-run Chinook salmon and steelhead/rainbow trout rearing (Upper Alluvial and Canyon Segments)

Hydraulic and structural data collection on four of the six juvenile rearing study sites was completed in FY 2006. The collection of additional bed topography data required to develop an accurate bed topography was completed for the remaining two study sites in FY 2007. We collected the data between the inflow and outflow transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate was visually assessed at each point.

Fall-run Chinook salmon and steelhead/rainbow trout spawning (Lower Alluvial Segment)

Water surface elevations were collected at all five spawning sites (Shooting Gallery, Lower Gorge, Upper and Lower Renshaw and Upper Isolation) at medium and high flows in FY 2007. The vertical benchmark elevations have been tied-in for all study sites except Lower Renshaw. Velocity sets were collected for the transects at all five study sites. Depth and velocity measurements were made by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 or a Price AA velocity meter. A tape or an electronic distance meter were used to measure stations along the transects. Substrate and cover along the transects were determined visually for all five study sites. Dry bed elevations and substrate and cover data along the transects were collected at all five study sites.

We collected the data between the inflow and outflow transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate were visually assessed at each point. Bed topography data collection was completed for the Shooting Gallery site in FY 2006, and for all of the Lower Gorge and Upper Renshaw and a portion of the Lower Renshaw site in FY 2007.

To validate the velocities predicted by the 2-D model within the study sites, depth, velocities, substrate and cover measurements were collected by wading with a wading rod equipped with a Marsh-McBirney model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by taking a total station shot on a prism held at each point where

depth and velocity were measured. A total of 50 representative points were measured throughout each site. All hydraulic and structural data collection was completed for Shooting Gallery, Lower Gorge and Upper Renshaw sites in FY 2007, with the exception of the stage of zero flow for Upper Renshaw. Work on Lower Renshaw and Upper Isolation sites is ongoing and is expected to be completed in FY 2008. We anticipate completing the data collection for the five spawning sites in FY 2008.

Hydraulic Model Construction and Calibration

Juvenile spring-run Chinook salmon and steelhead/rainbow trout rearing (Upper Alluvial and Canyon Segments)

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting data set is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 foot where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The PHABSIM transect at the outflow end of each site is calibrated to provide the WSEL at the outflow end of the site used by River2D. The PHABSIM transect at the inflow end of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL generated by River2D at the inflow end of the site match the WSEL predicted by the PHABSIM transect at the inflow end of the site⁶. The River2D model is run at the flows at which the validation data set was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover. The River2D model is also run at the simulation flows to use in computing habitat.

All data for the six spring-run Chinook salmon and steelhead/rainbow trout rearing sites have been compiled and checked. PHABSIM calibration has been completed for all six sites. Construction and calibration of the 2-D hydraulic models as described above of four of the six study sites was completed in FY 2007. Construction and calibration of the 2-D models for the remaining two study sites and running the production runs for the simulation flows is expected to be completed in FY 2008.

⁶ This is the primary technique used to calibrate the River2D model.

Fall-run Chinook salmon and steelhead/rainbow trout spawning (Lower Alluvial Segment)

All data have been compiled and checked for the three fall-run Chinook salmon and steelhead/rainbow trout spawning sites where data collection has been completed. Hydraulic model construction and calibration cannot begin on the Lower Alluvial sites until discharge data from Graham Mathews and Associates is received and local survey control is tied into known State Plane coordinate (northing, easting and vertical elevations) control points. It is anticipated that this work will be completed in FY 2008.

Habitat Suitability Criteria Development

Juvenile spring-run Chinook salmon and steelhead/rainbow trout rearing (Upper Alluvial and Canyon Segments)

Staff of the Red Bluff Fish and Wildlife Office (RBFWO) have been conducting snorkeling surveys specifically to collect rearing HSC for juvenile spring-run Chinook salmon and steelhead/rainbow trout in the Upper Alluvial and Canyon segments. The collection of Young of Year (YOY) spring-run Chinook salmon and steelhead/rainbow trout (fry and juveniles) rearing HSC data began at the end of FY 2004 with surveys conducted on the dates in Table 3. Snorkel surveys were conducted along the banks and in the middle of the channel. Depth, velocity, adjacent velocity⁷ and cover data were also collected on locations which were not occupied by YOY spring-run Chinook salmon and steelhead/rainbow trout (unoccupied locations). This was done so that we could apply a method presented in Guay et al. (2000) to explicitly take into account habitat availability in developing HSC criteria, without using preference ratios (use divided by availability). Traditionally, criteria are created from observations of fish use by fitting a nonlinear function to the frequency of habitat use for each variable (depth, velocity, cover, adjacent velocity). One concern with this technique is what effect the availability of habitat has on the observed frequency of habitat use. For example, if cover is relatively rare in a stream, fish will be found primarily not using cover simply because of the rarity of cover, rather than because they are selecting areas without cover. Guay et al. (2000) proposed a modification

⁷ The adjacent velocity was measured within 2 feet on either side of the location where the velocity was the highest. Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon and steelhead/rainbow trout reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of Clear Creek is around 4 feet (i.e., 4 feet x $\frac{1}{2}$ = 2 feet). This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth.

Table 3
Spring-run Chinook Salmon and Steelhead/Rainbow Trout Juvenile HSC Data Collection

Dates	Average Igo Flows (cfs)
September 24, 2004	213
January 14, 21, and 26-27, 2005	283
February 15, 2005	238
April 6 and 20, 2005	250
May 5, 11-13, 16, 23 and 26, 2005	264
June 7, 10, 13 and 23-24, 2005	198
July 28-29, 2005	154
November 22, 2005	199
December 7-8 and 14-16, 2005	216
January 25-26, 2006	194
February 10, 17 and 23, 2006	272
March 9-10, 15-17, 20-21, 27 and 29, 2006	378
April 6, 20-21, 24 and 26, 2006	333
May 1, 5-6, 9-10, 16-17, 24-25 and 30-31,	262
June 6-7, 2006	136
July 5 and 14, 2006	95
August 8, 2006	89
December 7, 15, 18-20 and 29	240
January 5, 8, 10, 17-19, 25-26 and 30-31	217
February 1, 5-7, 13-15, 21 and 27	261
March 7	255
April 3, 5, 10, 13, 17 and 26-27	235
May 1, 11, 15-18 and 23-24	227
June 7, 19 and 21	167
July 10, 12 and 19-20	106

of the above technique where habitat suitability criteria data are collected both in locations where fish are present and in locations where fish are absent. Criteria are then developed by using a logistic regression with presence or absence of fish as the dependent variable and depth, velocity, cover and adjacent velocity as the independent variables, and all of the data (in both occupied and unoccupied locations) are used in the regression.

Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator. In areas that could be sampled up to 20 feet from the bank, the above distances were doubled.

When conducting snorkel surveys adjacent to the bank, one person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY spring-run Chinook salmon or steelhead/rainbow trout were observed. The snorkeler recorded the tag number, the species, the cover code⁸ and the number of individuals observed in each 10-20 mm size class on a Poly Vinyl Chloride (PVC) wrist cuff. If one person was snorkeling per habitat unit, the side of the creek to be snorkeled would alternate with each habitat unit and would also include snorkeling the middle portion of some units. As an example, the right bank was snorkeled for one habitat unit, the middle of the next habitat unit was then snorkeled, and then the left bank was snorkeled of the next habitat unit and then the process was repeated.⁹ The habitat units were snorkeled working upstream, which is generally the standard for snorkel surveys. In some cases when snorkeling the middle of a habitat unit, the difficulty of snorkeling mid-channel required snorkeling downstream. If three people were going to snorkel each unit, one person snorkeled along each bank working upstream, while the third person snorkeled downstream through the middle of the unit. The distance to be snorkeled was delineated by laying out a tape along the bank as described previously for a distance of 150 feet or 300 feet. The average and maximum distance from the water's edge that was sampled, cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with a 150 or 300-foot-long tape) was also recorded. When three people were snorkeling, cover percentages were collected by each person snorkeling. After completing each unit, the percentages for each person were combined and averaged. The cover coding system used is shown in Table 2.

A 150 or 300-foot-long tape was put out with one end at the location where the snorkeler finished and the other end where the snorkeler began. Three people went up the tape, one with a stadia rod and data book and the other two with a wading rod and velocity meter. At every 20-foot interval along the tape, the person with the stadia rod measured out the distance from the bank given in the data book. If there was a tag within 3 feet of the location, "tag within 3" was recorded on that line in the data book and the people proceeded to the next 20-foot mark on the tape, using the distance from the bank on the next line. If the location was beyond the sampling distance, based on the information recorded by the snorkeler, "beyond sampling distance" was recorded on that line and the recorder went to the next line at that same location, repeating until reaching a line with a distance from the bank within the sampling distance. If there was no tag

⁸ If there was no cover elements (as defined in Table 2) within 1 foot horizontally of the fish location, the cover code was 0.1 (no cover).

⁹The Sacramento Fish and Wildlife Office Instream Flow Group designates left and right bank looking upstream.

within 3 feet of that location, one of the people with the wading rod measured the depth, velocity, adjacent velocity and cover at that location. Depth was recorded to the nearest 0.1 ft and average water column velocity and adjacent velocity were recorded to the nearest 0.01 ft/s. Another individual retrieved the tags, measured the depth and mean water column velocity at the tag location, measured the adjacent velocity for the location, and recorded the data for each tag number. Data taken by the snorkeler and the measurer were correlated at each tag location. For the one-snorkeler surveys, the unoccupied data for the mid-channel snorkel surveys was collected by establishing the distance to be snorkeled by laying out the tape on a bank next to the distance of creek that was to be snorkeled. After snorkeling that distance, the line snorkeled was followed down through the middle of the channel and the randomly selected distance at which the unoccupied data was to be collected was measured out toward the left or right bank, alternating with each 20 foot location along the tape. For the three-snorkeler surveys, unoccupied data was collected for each habitat unit snorkeled in this manner by alternating left and right bank or mid-channel for each habitat unit snorkeled. As an example, for the first habitat unit snorkeled, unoccupied data would be collected along the left bank. At the next unit, data would be collected along the right bank. At the next unit, the data would be collected as described previously using the mid-channel line snorkeled.

Results

To date, there have been 212 observations of YOY spring-run Chinook salmon, and 566 observations of YOY steelhead/rainbow trout (in this case the use of the term observations indicates when a sighting of one or more fish occurred). An observation can include observations of fry (<60 mm in length) and observations of juveniles (≥ 60 mm). Of the 212 YOY spring-run Chinook salmon observations, there have been 191 spring-run Chinook salmon observations of <60 mm fish and 34 spring-run Chinook salmon observations of ≥ 60 mm fish. Of the 566 YOY steelhead/rainbow trout observations, there have been 279 steelhead/rainbow trout observations of <60 mm fish and 314 steelhead/rainbow trout observations of ≥ 60 mm fish. HSC juvenile rearing data collection for ≥ 60 mm spring-run Chinook salmon will continue in FY 2008.

A total of 1,013 mesohabitat units have been surveyed to date. A total of 136,428 feet of near-bank habitat and 26,726 feet of mid-channel habitat have been sampled to date. Table 4 summarizes the number of feet of different mesohabitat types sampled to date and Table 5 summarizes the number of feet of different cover types sampled to date. We have developed two different groups of cover codes based on snorkel surveys we conducted on the Sacramento River: Cover Group 1 (cover codes 4 and 7 and composite [instream+overhead] cover), and Cover Group 0 (all other cover codes). A total of 85,509 feet of Cover Group 0 and 48,913 feet of Cover Group 1 in near-bank habitat, and 25,721 feet of Cover Group 0 and 740 feet of Cover Group 1 in mid-channel habitat, have been sampled to date.

Table 4
Distances Sampled for YOY Spring-run Chinook Salmon and
Steelhead/Rainbow Trout HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled (ft)	Mid-channel habitat distance sampled (ft)
Mid Channel Glide	3,969	693
Mid Channel Pool	56,820	9,369
Mid Channel Riffle	27,641	5,925
Mid Channel Run	45,798	8,508
Side Channel Glide	0	550
Side Channel Pool	1,180	520
Side Channel Riffle	200	365
Side Channel Run	2	664
Cascade	829	132

Table 5
Distances Sampled for YOY Spring-run Chinook Salmon and
Steelhead/Rainbow Trout HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled (ft)	Mid-channel habitat distance sampled (ft)
None	40,737	13,588
Cobble	13,637	7,757
Boulder	7,349	3,599
Fine Woody	39,155	416
Branches	22,329	376
Log	1,545	38
Overhead	1,461	26
Undercut	3,002	73
Aquatic Vegetation	5,096	616
Rip Rap	0	0
Overhead + instream	38,855	601

Fall-run Chinook salmon and steelhead/rainbow trout spawning (Lower Alluvial Segment)

Staff of the Red Bluff Fish and Wildlife Office have been collecting fall-run Chinook salmon spawning habitat suitability criteria during their biweekly snorkel surveys of Clear Creek, with this work having been completed in FY 2005. In addition, our office collected fall-run Chinook salmon spawning habitat suitability criteria data in our five Lower Alluvial Segment spawning study sites in FY 2007. For HSC data collection, all of the active redds, i.e., those distinguishable, but not covered with periphyton growth, were measured. The location of each redd was marked with a GPS unit in 2004 and 2005. The location of each redd found in our study sites in 2007 was determined with a total station. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about 2 to 4 feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within 6 feet of the pit of the redd. Depth was recorded to the nearest 0.1 foot (ft) and average water column velocity was recorded to the nearest 0.01 ft/second. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 1. Since data were collected within 2 weeks of redd construction (as a result of the biweekly surveys) it is likely that the measured depths and velocities on the redds are similar to those present during redd construction. Data were collected on a total of 297 fall-run Chinook salmon redds in 2004 and 2005 and on 464 redds in FY 2007. The HSC data has depths ranging from 0.5 to 3.5 feet, velocities ranging from 0.10 to 6.26 ft/s and substrate sizes ranging from 1-2 inches to 4-6 inches. Steelhead/rainbow trout spawning HSC data were not collected in the Lower Alluvial Reach since the HSC developed for steelhead/rainbow trout in the Upper Alluvial and Canyon Segments will be used to compute steelhead/rainbow trout spawning habitat over a range of discharges for the Lower Alluvial Reach.

Juvenile fall-run Chinook salmon rearing (Lower Alluvial Segment)

Snorkel surveys were initiated in FY 2007 to collect rearing HSC for juvenile fall-run Chinook salmon in the Lower Alluvial segment, using the same methods described above for spring-run Chinook salmon and steelhead/rainbow trout in the Upper Alluvial and Canyon segments, with surveys conducted on the dates in Table 6.

Results

To date, there have been 495 observations of YOY fall-run Chinook salmon (in this case the use of the term observations indicates when a sighting of one or more fish occurred). An observation can include observations of fry (<60 mm in length) and observations of juveniles (≥60 mm). Of the 495 YOY fall-run Chinook salmon observations, there have been 327 fall-run Chinook salmon observations of <60 mm fish and 173 fall-run Chinook salmon observations of ≥60 mm

Table 6
Fall-run Chinook Salmon Juvenile HSC Data Collection

Dates	Average Igo Flows (cfs)
January 22-25, 2007	216
March 19-22, 2007	230
May 14-17, 2007	226
Jul 9-12, 2007	112
Sep 4-6, 2007	82

fish. A total of 92 mesohabitat units have been surveyed to date. A total of 12,799 feet of habitat have been sampled to date. Table 7 summarizes the number of feet of different mesohabitat types sampled to date and Table 8 summarizes the number of feet of different cover types sampled to date. We have developed two different groups of cover codes based on snorkel surveys we conducted on the Sacramento River: Cover Group 1 (cover codes 4 and 7 and composite [instream+overhead] cover), and Cover Group 0 (all other cover codes). A total of 10,536 feet of Cover Group 0 and 2,263 feet of Cover Group 1 have been sampled to date. HSC juvenile rearing data collection for fall-run Chinook salmon will continue in FY 2008.

Habitat Simulation

Spring-run Chinook salmon and steelhead/rainbow trout spawning (Upper Alluvial and Canyon Segments)

In FY 2006, spring-run Chinook salmon and steelhead/rainbow trout spawning habitat was computed over a range of discharges for the six spawning sites. After peer review and responding to comments, a final report and peer review response-to-comments document were completed and issued in September 2007.

Juvenile spring-run Chinook salmon and steelhead/rainbow trout rearing (Upper Alluvial and Canyon Segments)

Once sufficient spring-run Chinook salmon juvenile rearing HSC data have been collected and rearing criteria have been developed, spring-run Chinook salmon and steelhead/rainbow trout rearing habitat will be computed over a range of discharges for the six spawning sites and six rearing sites in the Upper Alluvial and Canyon segments. Completion of this phase of the study and completion of the draft report will be subject to the time required to collect sufficient spring-run Chinook salmon rearing HSC data. Given the small number of observations of juvenile spring-run Chinook salmon gathered to date, it may be necessary to utilize the Clear Creek fall-run Chinook salmon juvenile criteria to be developed, spring-run Chinook salmon juvenile rearing HSC data from another creek or river with characteristics similar to Clear Creek, or

Table 7
Distances Sampled for YOY Fall-run Chinook Salmon HSC Data - Mesohabitat Types

Mesohabitat Type	Habitat distance sampled (ft)
Mid Channel Glide	3264
Mid Channel Pool	2823
Mid Channel Riffle	1658
Mid Channel Run	4207
Side Channel Glide	206
Side Channel Pool	162
Side Channel Riffle	50
Side Channel Run	429

Table 8
Distances Sampled for YOY Fall-run Chinook Salmon HSC Data - Cover Types

Cover Type	Habitat distance sampled (ft)
None	8311
Cobble	962
Boulder	207
Fine Woody	1643
Branches	656
Log	309
Overhead	341
Undercut	13
Aquatic Vegetation	354
Rip Rap	4
Overhead + instream	1741

conduct transferability tests using Clear Creek fall-run HSC or spring-run rearing HSC from another creek or river. Pending the collection of sufficient data to develop spring-run Chinook salmon HSC, we anticipate completing draft and final reports on the 2-D modeling of the spring-run Chinook salmon and steelhead/rainbow trout rearing study sites in the Upper Alluvial and

Canyon segments in FY 2008. The RBFWO has requested that a draft report be distributed to interested parties for comment in addition to peer review, as is being done with the Yuba River Study reports.

TUOLUMNE RIVER

In FY 2007, we began an investigation on anadromous salmonid rearing habitat in the Tuolumne River between La Grange Dam and river mile 22, using existing Geographic Information System (GIS) data. In January of 2007 the USFWS Anadromous Fish Restoration Program office requested a study of floodplain inundation as a function of flow for the entire anadromous reach on the Tuolumne, Stanislaus, Merced or the San Joaquin River, using existing data. The lower Tuolumne was chosen for this study, as appropriate GIS data from a previous study was available for this area. The flow-inundation area relationship was derived for fall-run Chinook salmon and steelhead/rainbow trout potential outmigration habitat in the Tuolumne River downstream of La Grange Dam. ARC GIS data used for this study was originally developed as part of the Federal Energy Regulatory Commission hydro-relicensing proceedings for the Don Pedro Project (Project No. 2299). The GIS layers used were first developed from aerial photos taken at flows between 100 and 8400 cubic feet per second (cfs) from 1988 through 1995. Shape files were edited to remove islands and isolated pond areas, which were actually gravel pits. Total area was then recalculated for all the remaining polygons for each flow/layer. A curve was then generated by plotting area in acres versus flow. We completed a draft report in FY 2007, which is currently being reviewed by Anadromous Fish Restoration Program staff. In FY 2008, we expect to conduct a peer review of this report and then finalize the report.

REFERENCES

- Guay, J.C., D. Boisclair, D. Rioux, M. Leclerc, M. Lapointe and P. Legendre. 2000. Development and validation of numerical habitat models for juveniles of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 57:2065-2075.
- U. S. Fish and Wildlife Service. 1999. Hydraulic modeling of Chinook salmon spawning sites in the Sacramento River between Keswick Dam and Battle Creek. U. S. Fish and Wildlife Service, Sacramento, CA.
- U. S. Fish and Wildlife Service, 2000. Effects of the January 1997 flood on flow-habitat relationships for steelhead and fall-run Chinook salmon spawning in the Lower American River. U. S. Fish and Wildlife Service, Sacramento, CA.
- U. S. Fish and Wildlife Service. 2003. Flow-habitat relationships for steelhead and fall, late-fall and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek.

APPENDIX A
YUBA RIVER JUVENILE CHINOOK SALMON AND
STEELHEAD/RAINBOW TROUT STRANDING SITES

Stranding Site #	MHU #	Stranding Flow (cfs)	Stranding Area (ft ²)
1	179-180	< 400	27144
2	173	685	1400
3	169	2128	253
4	170	2110	7356
5	168	3317	750
7	160-163	< 400	48742
7A	158-159	494	14712
8	141	< 400	14208
8A	141	829	268
8B	142	516	104
9	139/135	3338	3653
10	135	1672	4870
11	137/138	545	9
12	134	< 400	7980
13	131	< 400	7471
15	128	< 400	31534
16	117/119	1667	16434
17	50	307	10337
18	49	354	38045
19	45	2096	4205
20	45	891	3413
21	41, 43, 44	395	29859
22	40	1696	3231
23	37	1879	1057

Stranding Site #	MHU #	Stranding Flow (cfs)	Stranding Area (ft ²)
24	35	991	5433
25	28-33	750	14519
26	201	3597	10279
27	201	1953	16
28	201	2300	1511
29	199	3135	2230
30	194	2707	5625
31	192	1790	1200
32	190	634	1473
33	187	1188	246
34	120	< 400	1800
35	117	1908	2083
36	118	1735	351
37	113	2416	153129
38	113	1175	1000
39	112	4907	3547
40	112	3525	227615
41	112	3993	2068
42	112	1563	1339
43	112	3192	6510
44	94	597	18854
45	96-98	< 400	1219
46	100	1930	38947
47	100-104	2309	20690
48	89	1002	800
49	89	1813	1220

Stranding Site #	MHU #	Stranding Flow (cfs)	Stranding Area (ft ²)
49A	89	857	1200
49B	89	1001	750
50A	89	3069	300
50B	89	2702	15
50C	89	1249	420
51	83	2474	26917
52	82	990	476
53	80	1079	20576
54	80	1060	6600
55A	78	1017	7613
55B	78	3974	330
56	74	1813	150
57	71	1136	250049
58	69	2906	5685
59A	68/69	2698	960
59B	68/69	3409	861
60	63	485	18607
61	59	790	10774
62	56	2247	10989
63A	56	4380	3460
63B	56	2300	224
64	53	1949	9985
65	51	907	15168
66	24	903	3040
67	4	738	100
68	1	467	583